Flexibility of Electrolyzers Serving the Power System: Development Challenges for Hydrogen Transport and Storage Infrastructure in Auvergne–Rhône–Alpes

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In collaboration with La Région Auvergne-Rhône-Alpes

Disclaimers :

- This study is a prospective exercise and not a territorial planning document, even though the analyses aim to inform such planning discussions.
- All cost figures presented do not in any way represent service rates or tariffs. The cost assumptions are normative and can vary significantly from one project to another.
- It is important to note that the cost figures shown are not service rates or tariffs; they are highly dependent on the specific characteristics of each project (cost of electrolyzers, hydrogen network development, distance to the electrical grid connection point, and its technical specifications, etc.). Economic sensitivities to these parameters have already been analyzed in the hydrogen chapter of RTE's 2023 Forecast Report (BP 2023).

Executive Summary

As demonstrated by several national and European-level analyses, hydrogen transport and storage infrastructure in salt caverns plays a key role in the economic optimization of hydrogen production flexibility via electrolysis for the benefit of the power system. Analyses at the French level show that the net benefit could reach €1.2 billion per year by 2035 (value for the power system after deducting costs mainly related to hydrogen infrastructure).

These infrastructures enable temporal and geographical decoupling between hydrogen production and consumption. **This allows electrolytic hydrogen producers to take advantage of periods when electricity is inexpensive to produce, making electrolytic hydrogen production more competitive.** Furthermore, this decoupling enables hydrogen production to comply with sustainability criteria ("RFNBO[1]") defined by the European RED III directive and its delegated acts, while ensuring continuous supply to consumers. **This flexibility also helps reduce peak demand on the power system and more broadly optimize its operation.**

The Auvergne–Rhône–Alpes region, which has the largest national potential for salt cavern storage, including brine caverns available for conversion, is expected to play a central role in this domain. It has been identified as a strategic hub in the national hydrogen roadmap (see Figure below, from DGEC communications). It was previously highlighted by NaTran and RTE in their 2023 joint work as an ecosystem offering rapid gains for national electricity supply-demand balance with limited investment in hydrogen networks.

The region is also located on the route of the HYFEN project, a hydrogen transport infrastructure aiming to connect production, consumption, and storage sites in France, while enabling hydrogen transit between the Iberian Peninsula, France, and Germany.

Additionally, electric grid reinforcement projects are currently under study in the region. One such project is "Rhôna", which plans to create a new electrical substation in the Vallée de la Chimie, a zone currently constrained in available power. This project could offer up to 350 MW of new connection capacity, subject to firm commitments from one or more industrial projects in the area.

[1] Renewable Fuel of Non Biological Origin

Figure : Map illustrating DGEC communications related to the national hydrogen strategy

As part of its Ten-Year Network Development Plan[2] (SDDR) for 2040, RTE published its initial strategic orientations in early 2025. This plan has been subject to a public debate since September 4th, which will run until January 14th, 2026, after which it will be reviewed by the relevant authorities (Environmental Authority, Energy Regulation Commission, and the State). However, key insights were already drawn from the public consultation held in the first half of 2024 and are reflected in the version released on February 13th, 2025.

In the Auvergne–Rhône–Alpes region, two major zones were confirmed or proposed during this consultation to accelerate the connection of industrial projects, particularly those involving hydrogen production via electrolysis, subject to concrete progress and commitment from industrial stakeholders:

- **Priority Zone 2 ("P2"): The Chemistry Valley** (Vallée de la Chimie | Greater Lyon area), which is already being studied by RTE to enable the commissioning of new infrastructure by 2030, including a 350 MW electrical substation named "Rhôna".

- **Priority Zone 3 ("P3"): The "Grand Lyonnais" area**, identified based on contributions from the regional Prefecture, Regional Council, Regional Chamber of Commerce and Industry, and other stakeholders (including the PIPA Joint Syndicate and industrial actors). This zone, stretching from the Plaine de l'Ain Industrial Park to Salaise-sur-Sanne (Isère), via the Saint-Exupéry plain (Rhône/Isère), is expected to experience a short-term increase in electricity consumption. It also offers approximately 1,300 hectares of available land.

[2] RTE présente les grandes orientations de sa stratégie de transformation du réseau de transport d'électricité à l'horizon 2040 | RTE

These two zones are designed to support both the decarbonization of existing grid-connected clients and the establishment of new industrial sites, as highlighted by France Hydrogène and the Auvergne–Rhône–Alpes Region in their contributions to RTE's public consultation. Indeed, in the region, the cumulative volume of announced hydrogen projects alone amounted, at the time of the consultation, to over 500 MW of required electrical power by 2030, with the vast majority concentrated in the previously mentioned P2 and P3 zones.

This positions the Auvergne–Rhône–Alpes region at the heart of strategic challenges related to energy system competitiveness and optimization, at regional, national, and international levels. In this context, a prospective study was jointly initiated by NaTran, RTE, and Storengy, in collaboration with the Auvergne–Rhône–Alpes Region. The aim is to complement the findings of the national study jointly published by RTE and NaTran in July 2023, and to inform decisions regarding the development of hydrogen transport and storage infrastructure in connection with the growth of electrolysis in the region. While not a territorial planning document, the study is intended to support such planning efforts.

The study begins by comparing various hydrogen storage solutions, including batteries, surface hydrogen storage, and underground hydrogen storage. It demonstrates that connecting an electrolyzer to a shared underground storage facility via pipeline is the most cost-effective and space-efficient solution for an electrolysis project to ensure a high level of supply continuity for end users.

Building on this finding, the study then evaluates the economic impact of different connection configurations between electrolysis projects and the Etrez salt cavern storage site (Ain), tailored to the specific context of the Auvergne–Rhône–Alpes region.

Two hydrogen transport network configurations are analyzed:

i) Regional infrastructure pooling, enabling access to underground hydrogen storage in salt caverns located within the region (Etrez);
ii) National-scale pooling, involving infrastructures such as HYFEN, which allow for broader integration and optimization of hydrogen transport and storage across the national territory

For each configuration, the economic benefits of electrolyzer flexibility are assessed through the reduction in the full cost of hydrogen production. The study compares the required investments in hydrogen transport and storage infrastructure with the potential savings from producing hydrogen during periods of low electricity costs. The electricity cost assumptions used in this analysis are based on RTE's 2023 Forecast Report (BP 2023), specifically the Hydrogen chapter published in July 2024. The figures presented do not reflect market prices, but rather system-level cost estimates produced by RTE.

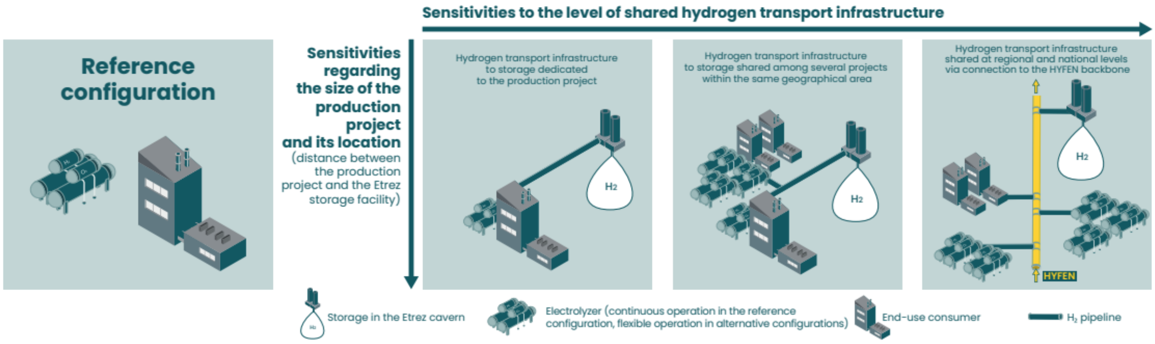


Figure: Overview of the analysed configurations

The analyses show that introducing flexibility into hydrogen production projects via electrolysis in the Chemistry Valley (Vallée de la Chimie) can generate savings of up to €0.90 per kg of H_2, representing approximately 18% of the total production cost for an electrolyzer operating continuously ("baseload mode"). These savings become tangible as soon as the pooling involves projects with a combined hydrogen production of approximately 14 kt per year.

For projects located further from the core zone — for example, in Savoie, within a 200 km radius — potential savings can reach up to €0.80 per kg of H_2, with noticeable benefits starting from a shared production volume of approximately 29 kt/year.

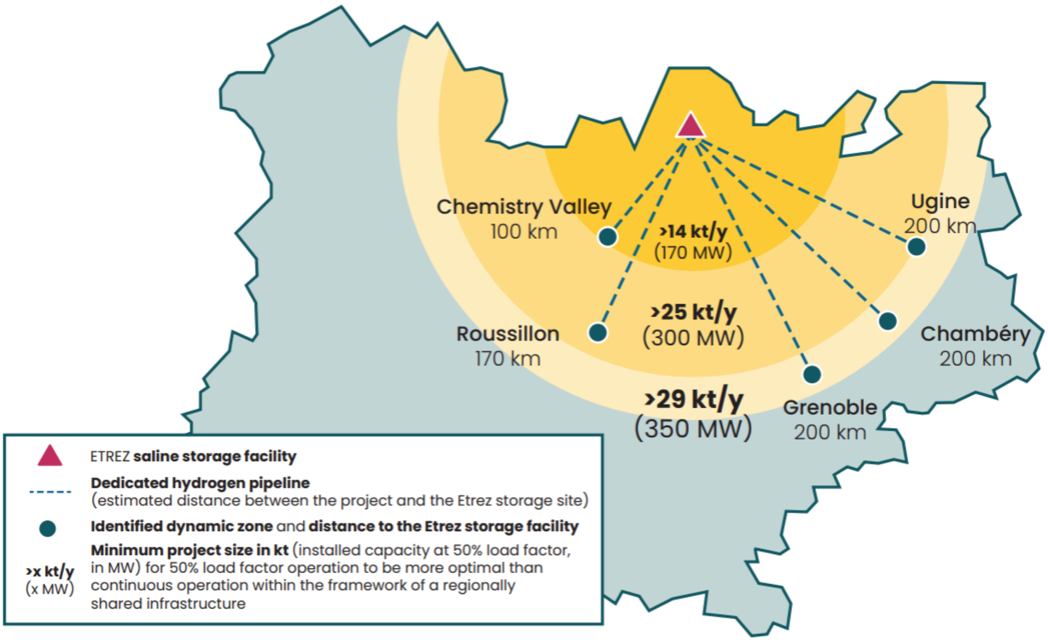
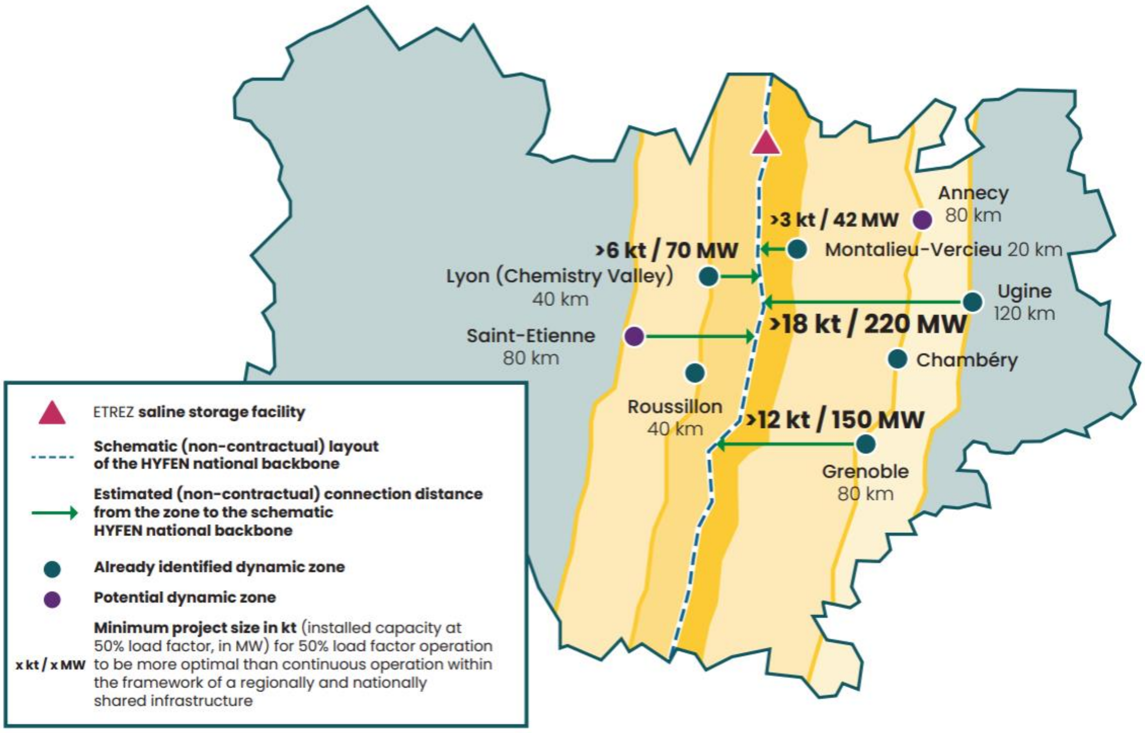


Figure: Minimum size of an electrolytic hydrogen production project from which flexible operation (50% load factor) becomes economically viable, depending on the distance to the Etrez storage site and based on the study's assumptions

The analyses show that cost savings from introducing flexibility into small-scale electrolysis projects increase significantly when these projects are connected to the national HYFEN backbone. Specifically, for projects located in the Chemistry Valley (Vallée de la Chimie), connecting to HYFEN to access the Etrez salt cavern storage can generate up to €0.5/kgH_2 in additional savings, on top of those achieved through regional infrastructure sharing (e.g., for a 17 kt hydrogen production project, total savings could reach €0.13 + €0.5/kg H_2).Connecting to the HYFEN backbone enables cost mutualization at the national or even international level. These additional savings stem from the broader scale of mutualization, moving from a regional to a national framework. Thus, regional projects may benefit from significant reductions in hydrogen production costs, even at smaller scales, thanks to the presence of the backbone infrastructure. In the case of the Chemistry Valley (Vallée de la Chimie), the regional mutualization threshold drops from 14 kt/year to just 6 kt/year, effectively halving the required scale. These figures are based on the assumptions detailed in Chapter 2.4 of the study.

These findings highlight that hydrogen transport and storage infrastructure is a critical technical enabler of the flexibility offered by electrolysis to the power system. The study demonstrates that mutualizing infrastructure strengthens the economic viability of flexibility: without such mutualization, the cost borne by each project could become prohibitive, discouraging investment and depriving the energy system of a valuable source of flexibility.

Therefore, a coordinated national and territorial planning approach for salt cavern-based hydrogen transport and storage infrastructure is essential. It is a prerequisite for triggering the necessary investments to fully leverage the potential of electrolysis, in support of the competitiveness of French hydrogen and the efficiency of the power system.



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